Feb. 21, 1967 A. WALSH ETAL 3,305,746

HIGH INTENSITY ATOMIC SPECTRAL LAMPS

Filed April 27, 1965 3 Sheets-Sheet 1

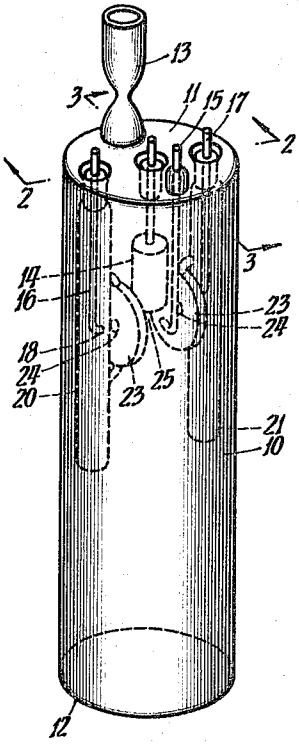


Fig. 1

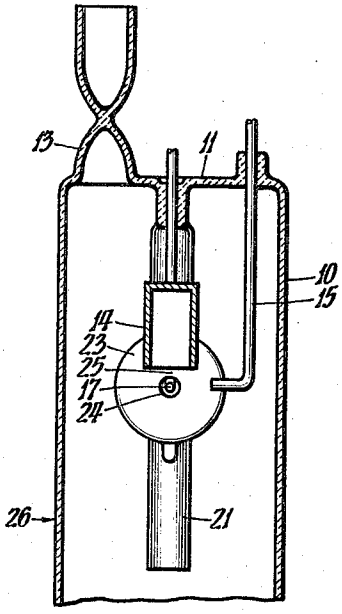


Fig. 3

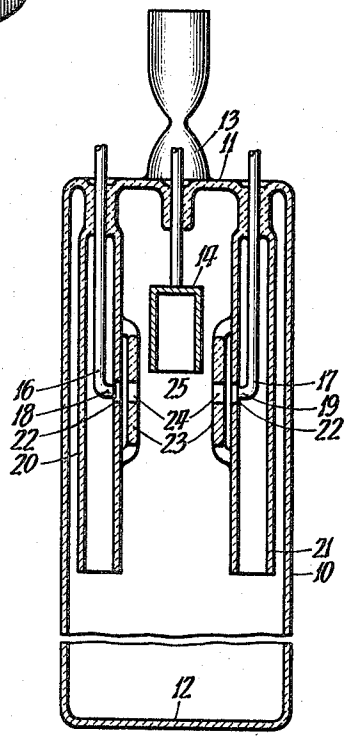


Fig. 2

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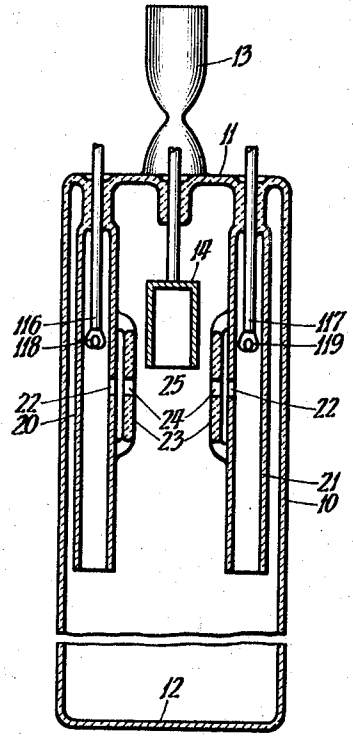


Fig. 1.

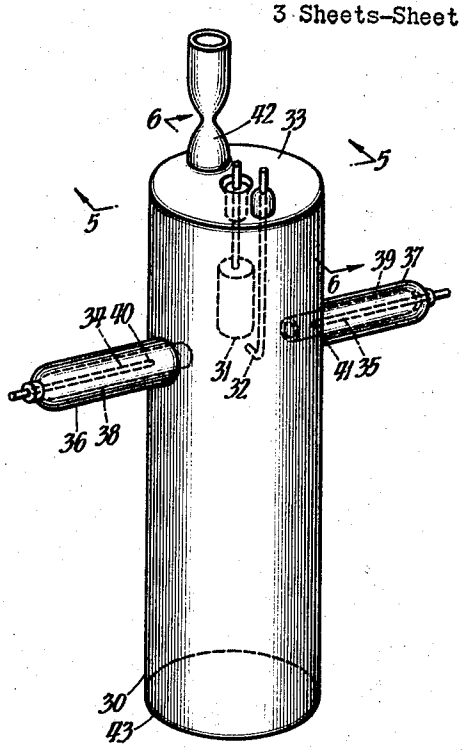


Fig. 4.

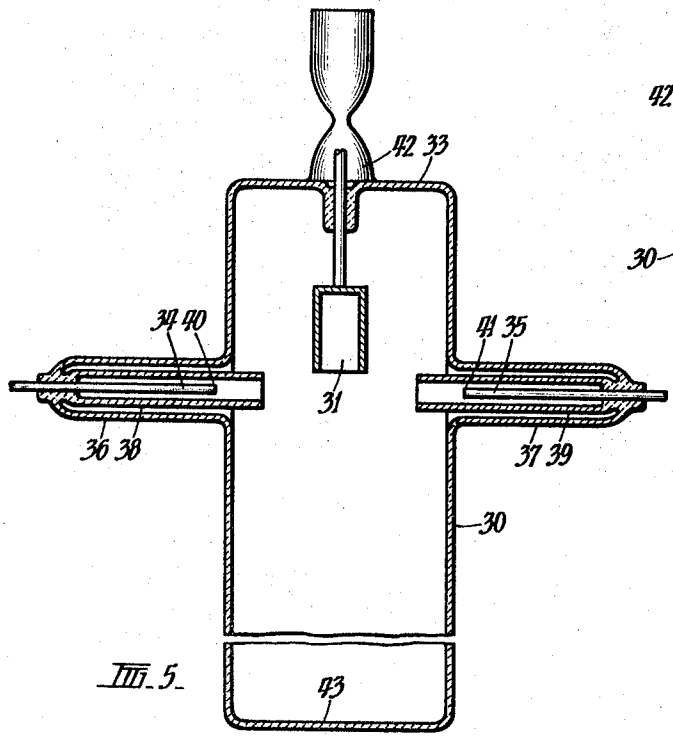


Fig. 5.

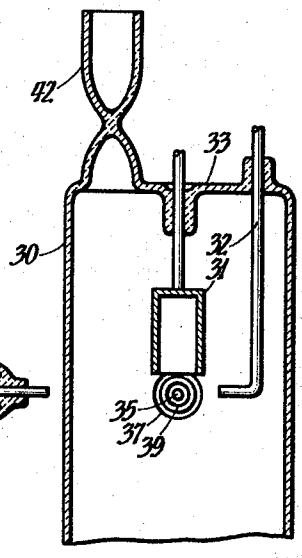


Fig. 6.

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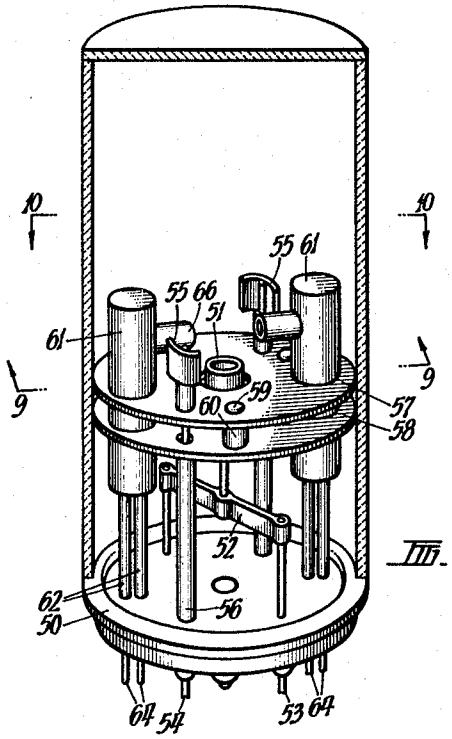


Fig. 8.

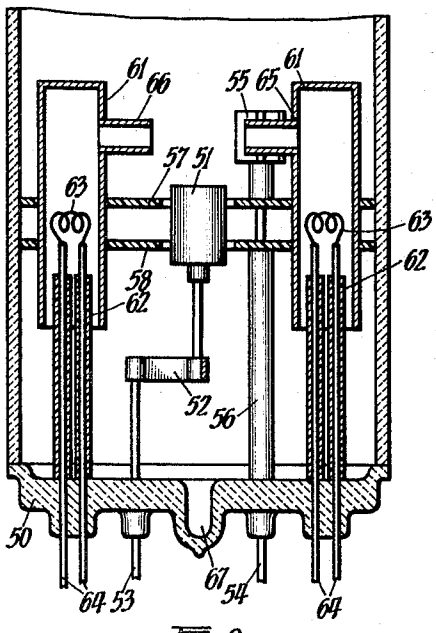


Fig. 9.

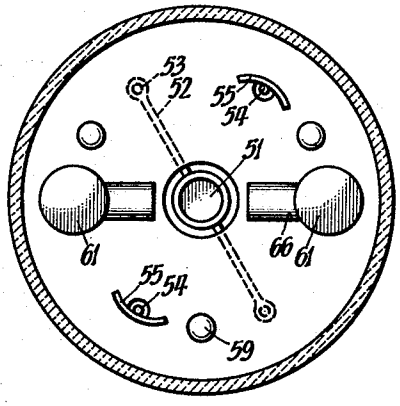


Fig. 10.

United States Patent Office 3,305,746 Patented Feb. 21, 1967

3,305,746

HIGH INTENSITY ATOMIC SPECTRAL LAMPS

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Filed Apr. 27, 1965, Ser. No. 451,206
Claims priority, application Australia, Oct. 15, 1962, 23,182/62
12 Claims. (Cl. 313—178)

This application is a continuation-in-part of our co-pending application Serial No. 314,350, filed October 7, 1963, now abandoned.

This invention relates to the production of atomic spectra, and in particular to electrical discharge lamps which are used in the production of sharp atomic spectral lines of high intensity. These spectral discharge lamps find applications in many fields of spectroscopy, particularly atomic absorption spectroscopy, and also provide a convenient source of reference spectra for wavelength-calibration or for line identification.

It is presently well known to produce atomic spectra by means of discharge lamps of two general types. In the first type, atomic vapour of the element the spectrum of which is required, is produced by vaporising a small quantity of the element by means of an electrical discharge of sufficient intensity which is struck between two electrodes of the discharge tube. This method is only suitable for the production of the atomic spectra of elements which have appreciable vapour pressures at temperatures below the softening point of the glass or silica envelope of the discharge tube. Such elements are, for example, sodium and mercury. It has not been found possible to adapt this type of discharge lamp to the emission of atomic spectra of high melting point metals such as iron, nickel, manganese, copper and others.

The second type of discharge lamp at present in use is the hollow-cathode discharge lamp, in which the cathode is shaped in the form of a hollow cylinder and is made of a material which consists wholly or partly of the element the spectrum of which it is required to obtain. This type of lamp suffers from the principal disadvantage that the electrical discharge between the anode and cathode serves to generate or produce an atomic vapour by sputtering from the cathode, and also to supply the excitation, which is necessary for the production of atomic spectra, to at least some of the atoms in the vapour. These two functions of the discharge cannot be separately controlled, and a variation in one parameter of the discharge, e.g. current or pressure, will affect both functions. The amount of atomic vapour produced must be limited to relatively small quantities if the widths of the spectral lines are not to be increased by self-absorption and resonance broadening. Thus the discharge current that can be used, and therefore the degree of excitation that can be imparted to the atomic vapour, are similarly limited. Consequently the intensities of the spectra emitted by such discharge lamps are necessarily limited if sharp lines are required.

It is the main object of this invention to produce an atomic spectral lamp in which the production of an atomic vapour by cathodic sputtering, and the excitation of the atoms of the vapour, can be controlled separately and independently. This property is particularly useful where it is desired to produce atomic resonance lines of high intensity. The term "resonance lines" may best be explained with reference to the known state of the art. Thus it is well known that, if radiation from an atomic spectral light source characteristic of a given element or elements, is allowed to fall on an atomic vapour of the same element or elements, selected lines in the spectrum

emitted by the light source will be partially absorbed by the atomic vapour. In technical parlance such lines are referred to as resonance lines. Other aims and objects of the invention will become apparent from the ensuing description.

The invention provides an atomic spectral lamp, in which an atomic vapour can be produced by cathodic sputtering caused by a first electric discharge, and wherein the atoms in said vapour may be excited by a second electric discharge.

According to one aspect of the invention there is provided an atomic spectral lamp comprising a first set of electrodes adapted to produce a first electric discharge which gives rise to an atomic vapour by cathodic sputtering, and a second set of electrodes, arranged and adapted to produce a second electric discharge which passes through the atomic vapour, whereby the atoms in the vapour may be excited. Preferably the cathode of the first set of electrodes is a hollow cathode. Preferably too the said first and second sets of electrodes are electrically isolated one from the other. Preferably also the electrodes of the said second set of electrodes are so arranged that the discharge therefrom is concentrated in a beam and passes through the atomic vapour produced in the vicinity of the cathode of the first set of electrodes. It is desirable that the electrodes of said second set of electrodes are partly enclosed in envelopes, which can be made from glass tubing, although as will be described later metal envelopes may be advantageously employed in certain constructions.

The invention also includes a method for producing atomic spectra of an element or elements, which comprises the steps of striking an electric discharge in a medium containing a rare gas at low pressure, producing an atomic vapour of said element or elements by cathodic sputtering caused by the discharge, and exciting the atoms of said vapour by passing a second electric discharge through the vapour.

An atomic spectral lamp according to this invention permits the amount of atomic vapour generated in the lamp to be controlled independently of the degree of excitation imparted to the atoms of the vapour. It is thus possible to increase the excitation without increasing the amount of atomic vapour, whereby intense resonance lines can be produced from atomic vapours at low partial pressures, avoiding any increase in the widths of the emitted spectral lines due to either self-absorption or resonance broadening. In practice, atomic spectra of intensities up to 1000 times those previously obtainable from known apparatus have been generated, while maintaining the line widths of the resonance lines at values of the same order as that previously obtainable only at the lower intensities.

In order that the invention may be more fully understood, four electrical discharge lamps constructed in accordance with the invention will now be described in detail by way of example with reference to the accompanying drawings, in which:

FIGURE 1 is a perspective view of one form of the atomic spectral lamp in accordance with this invention;

FIGURES 2 and 3 are sectional views along the lines 2—2 and 3—3, respectively, in FIGURE 1;

FIGURE 4 is a perspective view of an alternative design of an atomic spectral lamp in accordance with the invention;

FIGURES 5 and 6 are sectional views along the lines 5—5 and 6—6, respectively, in FIGURE 4;

FIGURE 7 is a sectional view of a lamp similar to that shown in FIGURES 1 to 3, showing a modified electrode assembly;

FIGURE 8 is a perspective view of a further alterna-

tive design of an atomic spectral lamp in accordance with this invention;

FIGURES 9 and 10 are sectional views along the lines 9—9 and 10—10, respectively, in FIGURE 8.

The lamp shown in FIGURES 1, 2 and 3 comprises a generally cylindrical, transparent glass envelope **10** which encloses two pairs of electrodes. The electrodes are mounted and sealed in the end surface **11** of the envelope **10**, while the other end surface **12** serves as a viewing window, through which the spectra produced within the envelope may be observed. An evacuating passage **13** is also formed in the end surface **11**.

The envelope **10** houses a first pair of electrodes **14, 15** and a second pair of electrodes **16, 17**; each of the electrodes being disposed in the longitudinal direction of the envelopes. The hollow cylindrical electrode **14** is mounted centrally within the end surface **11**. It is made wholly or in part of the element or elements the spectra of which are to be generated by the lamp. The electrode **15** is in the shape of a rod, and is located adjacent to the cylindrical electrode **14**.

The electrodes **16, 17** of the second pair of electrodes are so mounted in the end surface **11** of the lamp that they are disposed diametrically opposite each other. Both these electrodes are in the shape of rods, which have their inner ends or tips **18, 19** bent slightly so as to point towards each other, and are surrounded for their entire length by tubular protective covers **20, 21**. Each of these tubular covers is also made of glass and is fused to the base surface **11** at one end, but is open at the other end thereof, i.e. the end which is facing towards the viewing window **12**. An aperture **22** is formed in the wall of each tubular cover **20, 21** being located adjacent to the tip **18, 19** of the respective electrode **16, 17**. Outside each tubular cover there is a shield **23** which is disposed over the aperture **22**. The shield **23** has a generally centrally located opening **24**; the arrangement being that the electrode tips **18, 19**, the apertures **22** in the tubular covers **20, 21** and the openings **24** in the shields **23** are all aligned in a straight line, as can be seen from FIGURE 2.

In order to prepare a lamp for use, it is at first evacuated of air through the passage **13**, and is then filled with a rare gas, such as helium, neon, argon, or mixtures of these gases, at a pressure of the order of 1 mm. of mercury. After the normal "outgassing" and other standard discharge tube conditioning processes the evacuating passage is sealed, as shown in the drawings, whereafter the lamp is ready for operational use.

A potential difference of several hundred volts is now applied to the electrodes **14, 15** in such a way that the electrode **14** is the negative electrode or cathode, while electrode **15** is the positive electrode or anode. This has the effect of striking up an electrical discharge between the electrodes, and the discharge current, which is usually in the range of 1–100 ma., is maintained by it. The current supplied for this discharge is usually unidirectional but may be smooth or pulsating. It is also possible to use an alternating current supply but in this case it will be understood that sputtering will occur from the hollow electrode **14** only during the half-cycle when this electrode is negative with respective to the electrode **15**. Under the abovementioned pressure conditions within the envelope **10** of the lamp the discharge has the effect of giving rise to cathodic sputtering, in which the atoms of the cathode **14** are sputtered and form an atomic vapour within the cathode and in the inter-electrode space **25**. This type of discharge is known as a "hollow cathode discharge" since when viewed through the end window **12**, the inside of the cathode **14** appears luminous, and the luminous atomic vapour which contains some atoms which have been sufficiently excited by the discharge to produce spectra, exhibits atomic spectral lines characteristic of the element or elements of which the cathode is made.

A second electric discharge is then struck between the

electrodes **16, 17**. This discharge may be either alternating, pulsating or unidirectional. A potential difference of several hundred volts is maintained between the electrodes **16, 17** in order to generate the discharge while the discharge current which passes between the electrodes is in the region between 1 and 1000 ma. It will be appreciated that, because of the geometrical arrangement of the electrode tips **18, 19**, the apertures **22** in the tubular covers **20, 21**, and the apertures **24** in the shields **23**, the discharge passing between the electrodes **16, 17** is confined into a narrow beam which passes across and through the atomic vapour generated by cathodic sputtering in the inter-electrode space **25**.

The power supplies for the two discharges are so arranged that they are essentially electrically isolated from each other and thus it is not possible for any appreciable discharge current to pass from either electrode **14** or **15** to either electrode **16** or **17**.

The second discharge serves to excite many more atoms in the vapour produced by the first discharge, and thereby increases the intensity of the radiation which is emitted when these excited atoms return to a lower state of excitation (energy level), or to the ground state. Since the second discharge does not affect appreciably the total number of atoms in the vapour, there is no increase in the widths of the spectral lines due to self-absorption or resonance broadening effects, which could be the case if the intensity of the atomic spectral lines is sought to be increased merely by increasing the severity of the first discharge.

The envelope of the discharge lamp is usually made from glass or silica, and the viewing window may be made of any appropriate transparent material, such as glass, quartz, fused silica, sodium chloride etc., according to the region of the spectrum in which the emission spectra are to be observed. If required, the emission spectra generated by the lamp can be observed by looking into the lamp and at the inter-electrode space **25** in a direction transverse to the axis of the lamp i.e. as indicated by the arrow **26** in FIGURE 3. However, in practice it is found that both the walls of the envelope, and any observation windows located in the immediate vicinity of the cathode **14** become quickly covered by an opaque, sputtered layer of the cathode material. The end window **12**, however, is located sufficiently far away from the source of sputtering for it not to be affected by this deposition, and it is therefore preferable to use it for observation purposes.

FIGURES 4, 5 and 6 illustrate an alternative design of spectral lamp in accordance with this invention, and this will now be described briefly. As in the case of the previous lamp, the envelope **30** houses a first set of electrodes and a second set of electrodes. The first set comprises a hollow cylindrical cathode **31** and an anode **32**, both of which are mounted in the base **33** of the envelope **30**. The rod-like electrodes **34, 35** of the second set of electrodes are disposed in a direction transverse to the axis of the envelope, and are mounted within mutually oppositely located re-entrant portions **36, 37** which are formed in the side walls of the envelope. The electrodes **34, 35** themselves are also surrounded by tubular protective covers **38, 39** which extend beyond the tips **40, 41** of the electrodes and are open at their inner ends. As in the case of the previously described lamp, the tips **40, 41** of the second set of electrodes are located diametrically opposite each other, relatively to the cross-section of the envelope **30**.

The base surface **33** also accommodates an evacuating passage **42**, which is sealed after the lamp has been prepared ready for use. The other end surface **43** is utilized as a convenient observation window, and is spaced sufficiently far from the cathode **31** to avoid deposition of sputtered cathode material thereon.

The operation of the atomic spectral lamp shown in FIGURES 4, 5 and 6 is exactly analogous to the mode

of operation previously described, and does not therefore have to be repeated here. As in the case of the first lamp, the tubular protective covers **38, 39** serve to protect the electrodes **34, 35** from being fouled by deposition thereon of sputtered material, and also serve to concentrate the second discharge into a confined beam which passes through the sputtered atomic vapour.

According to one preferred aspect of the invention the cathode of the second set of electrodes is also a hollow cathode. It has been observed experimentally that this arrangement tends to improve the stability of the second discharge. In cases where the second discharge is alternating, both electrodes of the second set of electrodes may be hollow, i.e. in the form of hollow cylinders which are closed at one end.

It has been found that when secondary electrodes consisting simply of a wire or rod of metal, as shown in FIGURES 1 to 6, are used, certain difficulties may arise, due to the comparatively high voltages (of the order of several hundred volts) required to maintain the secondary discharge when the lamp is in operation. At such voltages the power dissipation of the secondary discharges becomes considerable as does the heat generated within the tube by the discharge, and difficulties arise in providing for the adequate dissipation of this heat, especially if the hollow cathode or the lamp contains or is made from a low melting metal e.g. zinc or cadmium. Furthermore, at these high voltages there is considerable sputtering from the secondary electrodes.

It is therefore desirable to modify the nature of the second set of electrodes, particularly with a view to lowering the voltage required to maintain the secondary discharge and, consequently, the power dissipation within the lamp. Considerable advantages arise if at least one of the electrodes of the second set (the cathode) is of the coated type, in which the surface of the electrode is coated with a thermionically emissive material. Such materials are well known as cathode coatings in the vacuum tube art and include the oxides and carbonates of certain metals, notably the alkali and alkaline earth metals.

The present invention, therefore, also provides an atomic spectral lamp of the type hereinbefore described wherein the second electric discharge is produced between electrodes at least one of which is coated with a thermionically emissive material.

The present invention also includes an atomic spectral lamp as hereinbefore described, wherein at least one of the electrodes of the second set is at least partly coated with a thermionically emissive material.

The coated electrode may be of any convenient form, such as, for example, a rod, tube or helix. The electrode may be of the cold type or alternatively may be adapted to be heated in known manner, e.g., indirectly in the case of tubular electrodes, by means of an electrically heated filament within the tube, or, in the case of an electrode which is itself a helical filament, by passing an electric current directly through the filament.

Preferably the electrodes of the second set are partly enclosed in protective envelopes. Such envelopes are preferably made of metal and are shaped and arranged so as to concentrate the secondary discharge into a beam which passes through the atomic vapour produced in the vicinity of the cathode of the first set of electrodes by the primary discharge.

In order that this modification of the invention may be more fully understood, two presently preferred discharge lamps in accordance with the invention will now be described in detail by way of example with reference to FIGURES 7 to 9 of the accompanying drawings.

The lamp shown in FIGURE 7 is identical in most respects with the lamp shown in FIGURE 1 and in the interests of clarity the same reference numerals are used to designate identical components. The lamp comprises as before an envelope **10** enclosing two pairs of electrodes

mounted and sealed in the end surface **11** of the envelope **10**, while the other end of surface **12** serves as a viewing window, through which the phenomena taking place within the envelope may be observed. An evacuating passage **13** is also formed in the end surface **11**.

The envelope **10** houses a first pair of electrodes **14, 15**, the electrode **14** being mounted centrally within the end surface **11** and being cylindrical in shape. It is made wholly or in part of the element or elements the spectra of which are to be generated by the lamp. The electrode **15** is in the shape of a rod, and is located adjacent to the cylindrical electrode **14**.

The electrodes **116, 117** of the second pair of electrodes are so mounted in the end surface **11** of the lamp that they are disposed diametrically opposite each other. Both these electrodes are in the shape of rods, which are provided at their inner ends or tips with small coiled filaments **118, 119** which are coated with a thermionically emissive material. The electrodes **116, 117** are surrounded for their entire length by tubular protective covers **20, 21**. Each of these tubular covers is also made of glass and is fused to the base surface **11** at one end, but may be open at the other end which is facing towards the viewing window **12**. An aperture **22** is formed in the wall of each tubular cover **20, 21** being located near to the filament **118, 119** on the end of the respective electrode **116, 117**. Outside each tubular cover there is a protective shield **23** which is disposed over the aperture **22**. The shield **23** has a generally centrally located opening **24**; the arrangement being that the apertures **22** in the tubular covers **20, 21** and the openings **24** in the shields **23** are all aligned in a straight line, as can be seen from FIGURE 7.

The lamp is prepared for use in the manner previously described.

In use, a potential difference of several hundred volts is applied to the electrodes **14, 15** to produce an electric discharge as previously described.

The second electrical discharge is then struck as before, by applying a potential of a few hundred volts between the electrodes **116, 117**. This discharge may be either alternating, pulsating or unidirectional. Unlike the lamps of FIGURES 1 to 3 and FIGURES 4 and 6 however, a potential difference of about 10 to 50 volts is sufficient to sustain the discharge between the electrodes **116, 117**.

FIGURES 8, 9 and 10 illustrate a further alternative and presently preferred design of a spectral lamp having heated coated cathodes, and this will now be described.

The elements of the lamp are all mounted on pins in the base **50**. Two sets of electrodes are provided as before. The first set comprises a hollow cylindrical cathode **51** mounted on the axis of the lamp and supported by a clamping strip **52** which is in turn supported on the ends of a pair of diametrically opposed base pins **53**.

Another pair of base pins **54** extends upwards from the base of the lamp and beyond the cathode **51**. A small curved metal "flag" or tab **55** is welded to each of the pins **54**, the flags **55** forming the anodes of the first set of electrodes.

The lower portion of each of the extended pins **54** is enclosed by a sleeve **56** made of ceramic material. The sleeve **56** also acts as a support for a pair of mica discs **57, 58** which are secured together in spaced relationship by pins **59** and ceramic spacers **60**, and which are perforated for the passage of the cathode **51**, the pins **54** and other elements of the lamp to be described. These other elements comprise two metal electrode shields **61**, which pass through and are supported by the discs **57, 58**.

Each of the shields **61**, encloses the upper portion of one of the electrodes of the second set of electrodes. Each of these electrodes comprises an oxide coated coiled filament **63** the ends of which are electrically connected to and supported by a pair of extended base pins **64**. The pins **64** are enclosed by ceramic sleeves **62** to prevent the occurrence of spurious discharges.

An aperture 65, is formed in the wall of each shield 61 facing the axis of the lamp and a short narrow metal tube 66 is fixed into and extends from each aperture 65, so that the tubes 66 point towards each other with their axes on a diameter of the lamp which passes a small distance above the cathode 51. The base 50 also carries an evacuating passage 67 which is sealed after the lamp has been prepared ready for use in the manner already described.

The operation of the lamp shown in FIGURES 8 to 10 is analogous to the mode of operation of the lamps previously described, except that prior to the initiation of the second electric discharge, one of the filaments 63, i.e., that which is selected to act as the cathode for the second discharge, is heated by connecting a suitable low voltage electric supply across the appropriate base pins 64. In a typical arrangement of this type with a filament current of 5 amperes at 1 volt, the second discharge can be maintained with a voltage of about 10 to 50 volts applied between the electrodes of the second set.

The invention has been described by reference to two specific designs of atomic spectral lamps, but obviously the principle of using one electrical discharge to produce an atomic vapour of an element or elements by cathodic sputtering, and employing a second electrical discharge to produce excitation of said atomic vapour, can be applied to lamps having different envelope shapes and electrode arrangements. Accordingly, the specific details described herein by way of an example are not to be construed as limiting the scope of the invention in any way.

We claim:

1. An atomic spectral lamp comprising a sealed envelope containing a rare gas at a low pressure, first electrode means located within the envelope for producing a first electric glow discharge which gives rise to an atomic vapor by cathodic sputtering, second electrode means for producing a second electric glow discharge, said second set of electrodes being so arranged within the envelope that said second discharge passes through said atomic vapor thereby to produce excitation of the atoms in said vapor giving rise to enhanced emission of atomic spectral radiation from said atoms, and a transparent viewing window in the envelope through which the phenomena inside the envelope may be observed.

2. An atomic spectral lamp as claimed in claim 1, wherein said first and second electrode means are each comprised of a pair of electrodes with the electrodes of the second set of electrodes partly enclosed in protective envelopes.

3. An atomic spectral lamp as claimed in claim 2, wehrein the protective envelopes are provided with constricted openings, whereby the electric glow discharge between the electrodes of the second set of electrodes is confined into a beam, which passes through the atomic vapor in the vicinity of the cathode of the first set of electrodes.

4. An atomic spectral lamp as claimed in claim 1, wherein at least one electrode of the said second set is at least partly coated with a thermionically emissive material.

5. An atomic spectral lamp as claimed in claim 4, wherein the said coated electrode is provided with heating means whereby the coating of the electrode may be heated.

6. An atomic spectral lamp as claimed in claim 4, wherein the said electrode is in the form of a tube and is heated by an internal electrically heated filament.

7. An atomic spectral lamp as claimed in claim 4, wherein the said electrode is in the form of a coil or helix and is heated by the passage of an electric current through the coil or helix.

8. An atomic spectral lamp comprising a sealed envelope containing a rare gas at a low pressure, first electrode means located within the envelope for producing a first electric glow discharge, said first electrode means including at least one hollow cathode which is adapted to give rise to an atomic vapor by cathodic sputtering, second electrode means for producing a second electric glow discharge, said second electrode means being electrically isolated from said first set and being so arranged within the envelope that said second discharge passes through said atomic vapor thereby to produce excitation of the atoms in said vapor giving rise to enhanced emission of atomic spectral radiation from said atoms, and a transparent viewing window in the envelope through which the phenomena inside the envelope may be observed.

9. An atomic spectral lamp as claimed in claim 8, wherein at least one electrode of the said second set is at least partly coated with a thermionically emissive material and provided with heating means whereby the said at least one electrode may be heated.

10. An atomic spectral lamp comprising a sealed cylindrical envelope containing a rare gas at a pressure of the order of 1 millimeter of mercury, first electrode means within the envelope and mounted in one end surface thereof, said first electrode means comprising a hollow cylindrical cathode and an anode, for producing a first electric glow discharge which is capable of giving rise by cathodic sputtering to an atomic vapor characteristic of the material of the cathode, second electrode means located within the envelope and being electrically isolated from said first means, for producing a second electric glow discharge, protective envelopes partly surrounding the electrodes of the second electrode means, said protecting envelopes being so arranged and so provided with openings that the second electric discharge is confined into a relatively narrow beam which passes through said atomic vapor in the vicinity of the hollow cathode of the first electrode means in a direction substantially perpendicular to the axis of said hollow cathode thereby to produce excitation of the atoms in said vapor giving rise to enhanced emission of atomic spectral radiation from said atoms, and a transparent viewing window in the other end surface of the envelope through with the phenomena inside the envelope may be observed.

11. An atomic spectral lamp as claimed in claim 10, wherein the cathode of the second set of electrodes is a hollow cathode.

12. An atomic spectral lamp as claimed in claim 10, wherein at least one electrode of the said second set comprises a filament which is at least partly coated with a thermionically emissive material and which is adapted to be heated by the passage of an electrical current therethrough.

No references cited.

DAVID J. GALVIN, *Primary Examiner.*